

~~Claims~~

- ~~Sub B1~~
- [c1] An improved initialization method for a communication system comprising the steps of:
- ~~estimating a timing offset utilizing an entire received DMT frame; and~~
  - ~~estimating a channel impulse response utilizing at least one pilot tone, wherein the received DMT frame further comprises the at least one pilot tone.~~
- [c2] The method of claim 1, wherein the steps of estimating a timing offset and estimating a channel impulse response are performed substantially simultaneously
- [c3] The method of claim 1, wherein the received DMT frame comprises a plurality of DMT frames.
- [c4] The method of claim 1, wherein the at least one pilot tone further comprises a plurality of pilot tones.
- [c5] The method of claim 1, wherein the step of estimating timing offset information further comprises the steps of:
- ~~transmitting a plurality of DMT frames of length  $N+LP$ , where  $N$  is equal to the number of samples comprising the DMT symbol and  $LP$  is equal to the number of samples comprising a cyclic prefix;~~
  - ~~receiving the plurality of DMT frames at a receiver;~~
  - ~~performing interpolation on the received DMT frames; and~~
  - ~~estimating an integer timing offset and a fractional timing offset from the DMT frames utilizing non-data aided maximum likelihood correlation with a pre-stored frame of length  $N+LP$ .~~
- [c6] The method of claim 5, further comprising the step of correcting for the integer timing offset in the time-domain.
- [c7] The method of claim 5, further comprising the step of correcting for the fractional timing offset in the frequency-domain.
- [c8] The method of claim 1, wherein the step of estimating the channel impulse response further comprises the steps of:

transmitting a plurality of DMT frames comprising a plurality of known pilot tones;  
receiving the DMT frames coincident with modem synchronization; and  
estimating the channel impulse response utilizing MMSE criterion through the pilot tones.

- [c9] The method of claim 8, further comprising synthesizing a 1-tap frequency domain equalizer based on the estimation of the channel impulse response.
- [c10] The method of claim 9, wherein the channel impulse response is padded with zeroes to accommodate for circular convolution prior to synthesizing the 1-tap frequency domain equalizer.
- [c11] The method of claim 8, wherein the plurality of pilot tones further comprises pilot tones modulated with a known symbol.
- [c12] An improved method of estimating a timing offset utilizing an entire received DMT frame.
- [c13] The method of claim 12, wherein the received DMT frame comprises a plurality of DMT frames.
- [c14] The method of claim 12, further comprising the steps of:  
transmitting a plurality of DMT frames of length  $N+LP$ , where  $N$  is equal to the number of samples comprising the DMT symbol and  $LP$  is equal to the number of samples comprising a cyclic prefix;  
receiving the plurality of DMT frames at a receiver;  
performing interpolation on the received DMT frames; and  
estimating an integer timing offset and a fractional timing offset from the DMT frames utilizing non-data aided maximum likelihood correlation with a pre-stored frame of length  $N+LP$ .
- [c15] The method of claim 14, further comprising correcting for the symbol timing offset in the time-domain responsive to the integer timing offset.
- [c16] The method of claim 14, further comprising correcting for the sample timing offset in the frequency-domain responsive to the fractional timing offset.

- [c17] An improved method of estimating a channel impulse response utilizing at least one pilot tone, wherein a received DMT frame further comprises the at least one pilot tone and the DMT frame is received during modem synchronization.
- [c18] The method of claim 17, wherein the received DMT frame comprises a plurality of DMT frames.
- [c19] The method of claim 17, wherein the at least one pilot tone further comprises a plurality of pilot tones.
- [c20] The method of claim 17, further comprises estimating the channel impulse response utilizing Minimum Mean Square Error criterion for the known pilot tones.
- [c21] The method of claim 20, further comprising synthesizing a 1-tap frequency domain equalizer based on the estimation of the channel impulse response.
- [c22] The method of claim 21, wherein the channel impulse response is padded with zeroes to accommodate for circular convolution prior to synthesizing the 1-tap frequency domain equalizer.
- [c23] The method of claim 20, wherein the plurality of pilot tones further comprise pilot tones modulated with a known symbol.
- [c24] An improved initialization method for modem communication comprising the steps of:  
transmitting a plurality of DMT frames of length  $N+LP$ , where  $N$  is equal to the number of samples comprising the DMT symbol and  $LP$  is equal to the number of samples comprising a cyclic prefix  
transmitting a plurality of pilot tones within the plurality of DMT frames;  
receiving the plurality of DMT frames at the receiver;  
extracting timing offset information from the DMT frames through correlation with a pre-stored DMT frame, wherein correlation is performed using the entire DMT frame of  $N+LP$  samples;  
performing interpolation on the received DMT frames resulting in an integer timing offset and a fractional timing offset; and

estimating the channel impulse response from the plurality of pilot tones within the received DMT frames.

[c25] The method of claim 24, further comprising:  
correcting for a symbol timing offset in the time-domain responsive to the integer timing offset; and  
correcting for a sample timing offset in the frequency-domain responsive to the fractional timing offset.

[c26] The method of claim 24, further comprises synthesizing a 1-tap frequency domain equalizer based on the estimation of the channel impulse response.

[c27] The method of claim 26, wherein the channel impulse response is padded with zeroes to accommodate for circular convolution prior to synthesizing the 1-tap frequency domain equalizer.

[c28] The method of claim 24, wherein the plurality of pilot tones further comprise pilot tones modulated with a known symbol.

[c29] An improved initialization method for modem communication comprising the steps of:  
transmitting a plurality of DMT frames of length  $N+LP$ , where  $N$  is equal to the number of samples comprising the DMT symbol and  $LP$  is equal to the number of samples comprising a cyclic prefix;  
transmitting a plurality of known symbols over  $L$  known pilot tones within the plurality of DMT frames;  
receiving the plurality of DMT frames at the receiver;  
performing interpolation on the received DMT frames;  
estimating an integer timing offset and a fractional timing offset from the DMT frames through correlation with a pre-stored DMT frame, wherein correlation is performed using the entire DMT frame of  $N+LP$  samples;  
correcting for a symbol timing offset in the time-domain responsive to the integer timing offset;  
correcting for a sample timing offset in the frequency-domain responsive to the fractional timing offset;

estimating the channel impulse response utilizing the L pilot tones within the received DMT frames;  
padding the channel impulse response with (N-L) zeroes; and  
synthesizing a 1-tap frequency domain equalizer based on the channel impulse response.

[c30] An improved system for modem communication comprising:  
a timing offset estimator adapted to estimate a timing offset utilizing an entire received DMT frame; and  
a channel impulse response estimator adapted to estimate a channel impulse response utilizing at least one pilot tone, wherein the received DMT frame further comprises the at least one pilot tone.

[c31] The system of claim 30, wherein the timing offset estimator and the channel impulse response estimator are adapted to operate substantially simultaneously.

[c32] The system of claim 30, wherein the received DMT frame comprises a plurality of DMT frames.

[c33] The system of claim 30, wherein the at least one pilot tone further comprises a plurality of pilot tones.

[c34] The system of claim 30, wherein the timing offset estimator further comprises:  
a transmitter adapted to transmit a plurality of DMT frames of length  $N+LP$ , where N is equal to the number of samples comprising the DMT symbol and LP is equal to the number of samples comprising a cyclic prefix;  
a receiver adapted to receive the plurality of DMT frames;  
an interpolator adapted to perform interpolation on the received DMT frames;  
and  
a correlator adapted to estimate an integer timing offset and a fractional timing offset from the DMT frames utilizing non-data aided maximum likelihood correlation with a pre-stored frame of length  $N+LP$ .

[c35] The system of claim 34, further comprising a symbol clock correction circuit adapted to correct a symbol timing offset in the time-domain responsive to the

integer timing offset.

- [c36] The system of claim 34, further comprising a rotor-delay correction circuit adapted to correct a sample timing offset in the frequency-domain responsive to the fractional timing offset.
- [c37] The system of claim 30, wherein the channel impulse response estimator estimates the channel response utilizing a Minimum Mean Square Error criterion of the known pilot tones.
- [c38] The system of claim 37, further comprising a synthesizer adapted to synthesize a 1-tap frequency domain equalizer based on the estimation of the channel impulse response.
- [c39] The system of claim 38, wherein the channel impulse response is padded with zeroes to accommodate for circular convolution prior to synthesizing the 1-tap frequency domain equalizer.
- [c40] The method of claim 37, wherein the plurality of pilot tones further comprise pilot tones modulated with a known QAM symbol.
- [c41] An improved system for estimating a timing offset utilizing an entire received DMT frame.
- [c42] The system of claim 41, wherein the received DMT frame comprises a plurality of DMT frames.
- [c43] The system of claim 41, wherein the timing offset estimator further comprises:  
a transmitter adapted to transmit a plurality of DMT frames of length  $N+LP$ , where  $N$  is equal to the number of samples comprising the DMT symbol and  $LP$  is equal to the number of samples comprising a cyclic prefix;  
a receiver adapted to receive the plurality of DMT frames;  
an interpolator adapted to perform interpolation on the received DMT frames;  
and  
a correlator adapted to estimate an integer timing offset and a fractional timing offset from the DMT frames utilizing non-data aided maximum likelihood correlation with a pre-stored frame of length  $N+LP$ .

- [c44] The system of claim 43, further comprising correcting a symbol clock correction circuit adapted to correct a symbol timing offset in the time-domain responsive to the integer timing offset.
- [c45] The system of claim 43, further comprising a rotor-delay correction circuit adapted to correct a sample timing offset in the frequency-domain responsive to the fractional timing offset.
- [c46] An improved system for estimating a channel impulse response utilizing at least one pilot tone, wherein a received DMT frame further comprises the at least one pilot tone and the DMT frame is received during modem synchronization.
- [c47] The system of claim 46, wherein the received DMT frame comprises a plurality of DMT frames.
- [c48] The system of claim of claim 46, wherein the at least one pilot tone further comprises a plurality of pilot tones.
- [c49] The system of claim 46, wherein the channel impulse response estimator estimates the channel response utilizing a Minimum Mean Square Error criterion of the known pilot tones.
- [c50] The system of claim 49, further comprising a synthesizer adapted to synthesize a 1-tap frequency domain equalizer based on the estimation of the channel impulse response.
- [c51] The system of claim 50, wherein the channel impulse response is padded with zeroes to accommodate for circular convolution prior to synthesizing the 1-tap frequency domain equalizer.
- [c52] The method of claim 46, wherein the plurality of pilot tones further comprise pilot tones modulated with a known symbol.
- [c53] An improved system for modem communication comprising the steps of:  
a transmitter adapted to transmit a plurality of DMT frames of length  $N+LP$ , where  $N$  is equal to the number of samples comprising the DMT symbol and  $LP$  is equal to the number of samples comprising a cyclic prefix;

the transmitter adapted to transmit a plurality of pilot tones within the plurality of DMT frames;

a receiver adapted to receive the plurality of DMT;

a timing offset estimator adapted to estimate a timing offset from the DMT frames through correlation with a pre-stored DMT frame, wherein correlation is performed using the entire DMT frame of  $N+LP$  samples;

an interpolator adapted to interpolate the received DMT frames resulting in an integer timing offset and a fractional timing offset; and

a channel impulse estimator adapted to estimate the channel impulse response from the plurality of pilot tones within the received DMT frames.

[c54] The system of claim 53, further comprising:

a symbol clock correction circuit adapted to correct a symbol timing offset in the time-domain responsive to the integer timing offset; and

a rotor-delay correction circuit adapted to correct a sample timing offset in the frequency-domain responsive to the fractional timing offset.

[c55] The system of claim 53, further comprising a synthesizer adapted to synthesize a 1-tap frequency domain equalizer based on the estimation of the channel impulse response.

[c56] The system of claim 55, wherein the channel impulse response is padded with zeroes to accommodate for circular convolution prior to synthesizing the 1-tap frequency domain equalizer.

[c57] The system of claim 53, wherein the plurality of pilot tones further comprise pilot tones modulated with a known symbol.

[c58] An improved system for modem communication comprising:  
a transmitter adapted to transmit a plurality of DMT frames of length  $N+LP$ , where  $N$  is equal to the number of samples comprising the DMT symbol and  $LP$  is equal to the number of samples comprising a cyclic prefix  
the transmitter transmitting a plurality of known symbols over  $L$  known pilot tones within the plurality of DMT frames;  
a receiver adapted to receive the plurality of DMT frames;



an interpolator adapted to interpolated the received DMT frames;  
a timing offset estimator adapted to estimate an integer timing offset and a fractional timing offset from the DMT frames through correlation with a pre-stored DMT frame, wherein correlation is performed using the entire DMT frame of  $N+LP$  samples;  
a symbol clock corrector circuit adapted to correct a symbol timing offset in the time-domain responsive to the integer timing offset;  
a delay-rotor circuit adapted to correct a sample timing offset in the frequency-domain responsive to the fractional timing offset;  
a channel impulse response estimator adapted to estimate the channel impulse response utilizing the  $L$  pilot tones within the received DMT frames;  
a circular convolution circuit adapted to pad the channel impulse response with  $(N-L)$  zeroes; and  
a synthesizer adapted to synthesize a 1-tap frequency domain based on the channel impulse response.

